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Technical Report: NAVTRAEQUIPCEN IH-249

LASER PLOTTING PROJECTOR

Electronics & Acoustics Laboratory
Naval Training Equipment Center
Orlando, Florida 32813

Final Report for Period June 1974 - June 1975

November 1976

DoD Distribution Statement

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ORLANDO, FLORIDA 32813

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November 1976

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
NAVTRAEQUIPCEN-IH-249

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
6 LASER PLOTTING PROJECTOR

5. TYPE OF REPORT & PERIOD COVERED
9 Final Rep[redacted]t,
Jun[redacted]974 — Jun[redacted]975

6. PERFORMING ORG. REPORT NUMBER
14 NAVTRAEQUIPC[redacted]-IH-249

7. AUTHOR(s)
10 Herbert Berke

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Electronics & Acoustics Laboratory
Naval Training Equipment Center
Orlando, Florida 32813

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
NAVTRAEQUIPCEN Task No. 5722-01

11. CONTROLLING OFFICE NAME AND ADDRESS
Naval Training Equipment Center
Orlando, Florida 32813
12 50p.

12. REPORT DATE
11 Nov[redacted]1976

13. NUMBER OF PAGES
48

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Laser, memories, beam deflection, training device technology, charge coupled devices.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
This report has been compiled to provide a means of obtaining a wide-angle, large screen, laser display for training purposes. Visits were conducted to various Government facilities to investigate present display techniques and a search analysis was performed to determine the past and present studies that had been done on this subject. The advantages and disadvantages of each part of the display system were researched and a conceptual design was initiated based on the gathered data. The Appendix included in this report gives a brief summary of work that has been performed by the various Government facilities.

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SECTION I

INTRODUCTION

This report documents results of a study to investigate the feasibility of a wide-angle, large screen laser display to be used for training situations.[1] Present plotting projectors have maintenance problems that add to the cost of operating and training. These costs and downtime of the projectors have discouraged the use of large screen displays. As a result, a new approach has used multiple television monitoring stations. This eliminated the problems of projectors but at the cost of losing the versatility of a large screen display and larger audience participation. Therefore, a new approach was desired to obtain large screen capabilities. Various studies, referenced in this report, were made in the use of a laser and associated scanning methods. The nature of the light output of lasers lends itself to modulation in intensity and direction because of its monochromaticity and uniphase wave front, a wide selection of hues, and a high resolution because of its diffraction limited beam spread.

A major advantage of a large screen display using the laser system is its ability to project the display information to any desired size using passive optics.[2]

[1] Wolff, H. H., Plotting Projector, U.S. Patent #3,739,370, June 1973, NAVTRAEQUIPCEN.

[2] Senf, H. R., Laser Displays, SMPTE Report #100-2, Oct. 1966.

SECTION II

STATEMENT OF THE PROBLEM

The need exists for a large screen multitrack tactical display for training devices showing present track positions only, with the capability of displaying prior track history. Motivation for these large screen efforts is provided by the trend to group interaction, a decision making process, involving the skills of many operators, which is increasingly evident in military, space, and air traffic command-and-control centers.

The problems posed by projectors now in use are: bandwidth limits, erratic duty cycles, data mixing and maintenance.

Plotting projectors used in training devices present tracks and positions of own and other targets for instructor and observer use. In current projectors scribed glass slides are used and must be recoated after each use and debriefing. Also, slide storage of track and position information is cumulative rather than selective.

Writing times vary: for mechanical scribe systems, 10-45 symbols per second can be displayed, depending on screen position of consecutive symbols; for all electronic writing, the rates are improved by two orders of magnitude. While mechanically scribed and photochemical film-projection displays are providing service, they cannot begin to match the dynamic, high-pattern complexity (mixed synthetic and video), colored displays provided by CRT on smaller screens. Then why not project CRT displays on to larger screens? The answer lies in available contrast ratios. For instance, a Schmidt optics system, which is quite useful for projecting the CRT faceplate image on a 3 ft by 3 ft screen, develops a washed-out image on a 5 ft by 5 ft screen. The CRT image resolution and contrast can be improved only by raising the electron-beam energy levels, but this results in tube burnouts and X-ray emission, hardly appropriate for use by a military training facility.[3]

Attempts to correct these shortcomings are leading to development of displays with viewing areas in the hundred square foot range, and rest on a wide variety of electrooptical, chemical and mechanical techniques. These include lasers, light valves, photochromic materials, solid-state devices, and new CRT concepts.

General requirements for the large-screen dynamic display seem straightforward enough: screen sizes in the fifty to 200 sq ft range, depending on group sizes and sensor field of view; contrast ratios of 5:1 to 60:1, depending on display brightness and ambient lighting; high resolution, in some cases approaching lithographic quality; color, perhaps three to seven distinct chromatics; multiple access of manual, computer, and video data in real-time; and, finally, low costs, both initial and operating.

The objective of this report is to determine the feasibility of producing a plotting projector for wide-angle display, which does not have the problems associated with mechanical scribing techniques.

[3] Thomas, Paul G., Large Screen Displays, Space/Aeronautics, May 1967.

SECTION III

PROCEDURE

An in-depth literature search of wide-angle display systems was conducted. All available data sources were used to review past, current, and near future display requirements. The data sources are as follows:

a. Source: Independent Research & Development (IR&D)

Method: Computer Search 1972 - 1975

Extent of Survey: 17 reports were perused with a large percentage from RCA, Hughes, and Westinghouse. The information obtained from these companies stated that most of the research in large screen display technologies was stopped due to lack of funding and lack of interest by a user.

b. Source: NASA

Method: Computer Search 1968 - 1975

Extent: 108 unclassified and 28 classified documents were studied.

c. Source: DOD (classified) - 200 DD 1498 documents and a report bibliography led to various contacts and to 28 studies on large screen displays.

The work that has been performed by other facilities specified the following general requirements.[4]

a. Screen: Greater than $10m^2$, rear projection (for eye safety) with a desired brightness of 5 - 20 foot-lamberts. The laser projector would be approximately 3m from the screen and the system would have a total deflection angle of ± 15 to ± 20 degrees.

b. Laser: Multicolor, at least three colors, with an optical wavelength from 450nm to 650nm.

c. Position Accuracy: A resolution on the screen of ± 1 beam diameter.

d. Low cost, both initial and operating.

The design criteria was then based on this information and includes features of real-time, random access, computer driven, multiple tracks, and a sample rate that could be set at one per second with a storage capability for past tracking.

[4] Kidd, E. T., "Lasers for Training Devices - Final Report", Technical Report, NAVTRADEVCEN 1651-1, Sep. 1965.

SECTION IV

RESULTS

The design that is shown in this report of a wide-angle laser deflection system incorporating the capability of a memory is based on an intensive study of work that has been done and on state-of-the-art techniques. The results are shown in Table 1. It was determined that:

a. A laser having the characteristics of a 1mr beam divergence and a 1mm beam diameter will produce a 3mm beam diameter (BD) on a screen that is 3m away. This will give a total resolution of 1000 X 1000 spots.

b. Beam deflection galvanometers can easily obtain ±25 degrees with a time response of 500ms F.S. This computes to be 500 BD in 500ms, or 1BD/ms. Since a 30ms scan rate is needed for tracking, or 30ms/100 BD, a 30ms/BD response time is required. A fast response galvanometer should be able to meet this specification.

Consultation between Dennis Breglia of the Naval Training Equipment Center (NAVTRAEQUIPCEN) Physical Sciences Laboratory, and the Electronics and Acoustics Laboratory, resulted in the information on typical laser specifications included in Appendix A. The laser, modulators, x-y deflectors, related drivers, and optics, can be purchased as units from various manufacturers. A typical cost breakdown is shown in Appendix A.

TABLE 1. RESULTS OF STUDY

1. Laser	Krypton 1 watt output 1mm beam diameter 1mr beam divergence
2. Modulator	three-color electrooptic for 100% modulation
3. Deflector	Galvanometer (x, y) 1/2ms F.S. response $\pm 25°$ deflection angle
4. Screen	Rear Projection Size, 3m x 3m
5. Memory	Solid-State Total Storage, 4k per color Word length, 21 bits per color Random Access
6. Tracking Specification	Multicolor $\pm$ beam diameter position resolution 3mm beam diameter 1000 x 1000 resolvable spots

The following information is an explanation of the schematics and block diagrams of Figures 1-5.

Figure 1. Laser and Beam Control. The Krypton laser, filters, modulators, and deflectors, can be purchased as off-the-shelf items. Typical parts are listed in Appendix A.

Figure 2. Storage Register Input. The computer inputs data to the storage registers in the form of a three-step, 23-bit code, every one second. This information consists of:

10 bit code for x

10 bit code for y

2 bit code for write (red, blue, green)

1 bit code for modulator (On/Off)

This 3-step code can be dumped into the registers as fast as they can respond which is in nano-seconds. A logical time could be 1 micro-second per step every second. The 2-bit code will put:

0,1 for red

1,0 for blue

1,1 for green

into the registers by clocking through the 'OR' gate. This clock also dumps the three 10-bit x, 10-bit y code into the registers along with the 1-bit for modulation. When the green code of 1,1 is sensed by the 'NAND' gate, a one-shot multivibrator is activated for T=100MS. This is the clock for the sample COUNTER.

Figure 3. Sample Counter and Comparators. The sample counter keeps a count of all the data that has been fed in from the computer. This counter, the comparators, and the address counters, are the three circuits that record the data into the memory in the correct sequence. The magnitude comparators sense when the sample count is equal to the address count and allow the gate to activate a one-shot number 2 with a time of T=100 microseconds. This allows the 500 kHz clock to pass through a gate into a 3-pulse counter. These three pulses are fed back to the OR gate of Figure 2 to step all new information into the memory. The output of the 3-pulse counter resets O/S #1 and O/S #2 until a new cycle is initiated.

Figure 4. Memory and Deflectors. At the correct time, data is written into the memory. This data includes the one-bit code which activates the modulators for the three colors. The output of the memory is a 60 bit word for x/y deflection, and a 3 bit code for the modulators. The x/y data is fed into 10-bit digital to analog converters (DACS) and then to adjustable gain operational amplifiers. The amplifiers are adjusted for proper input to the drivers for the deflectors. The 3-bit

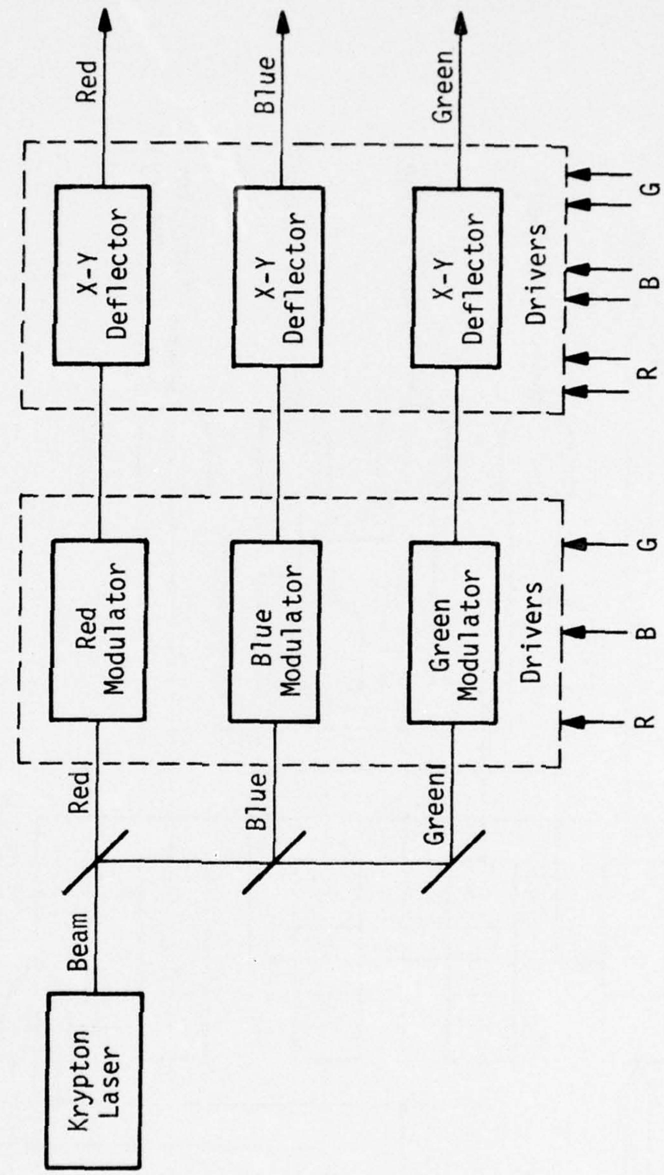

Figure 1. Laser and Beam Control.

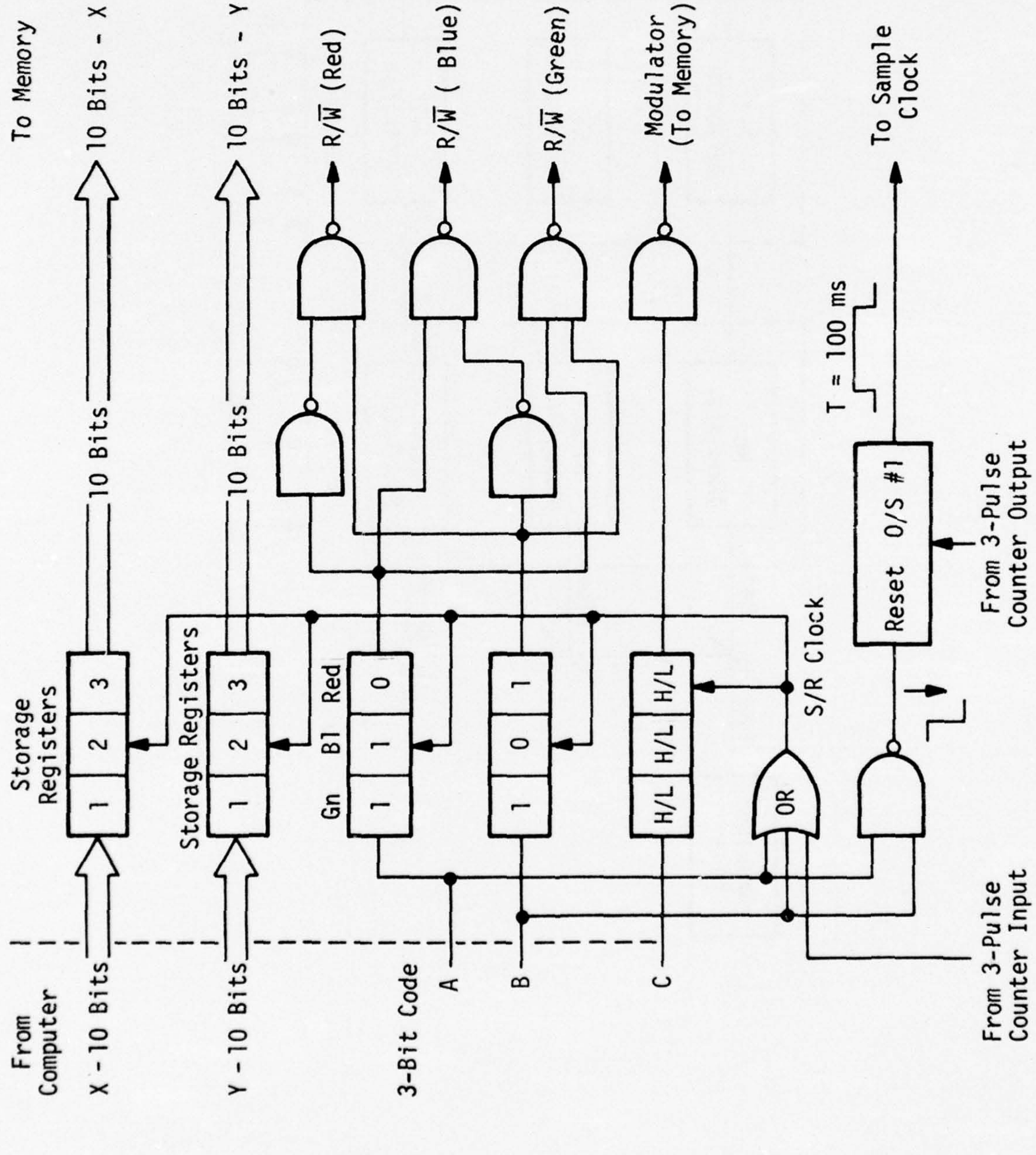

Figure 2. Storage Register Input.

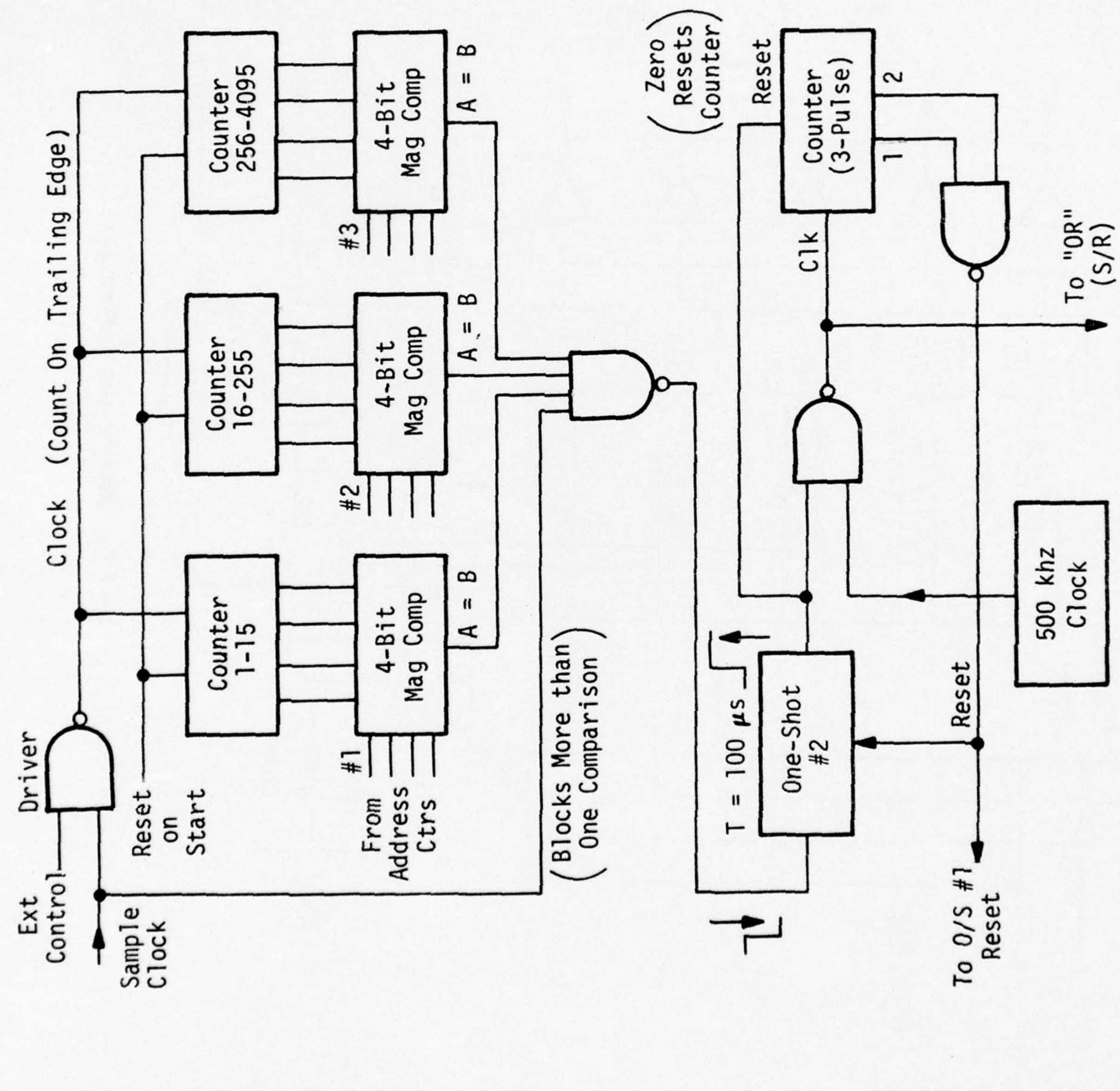

Figure 3. Sample Counter and Comparators.

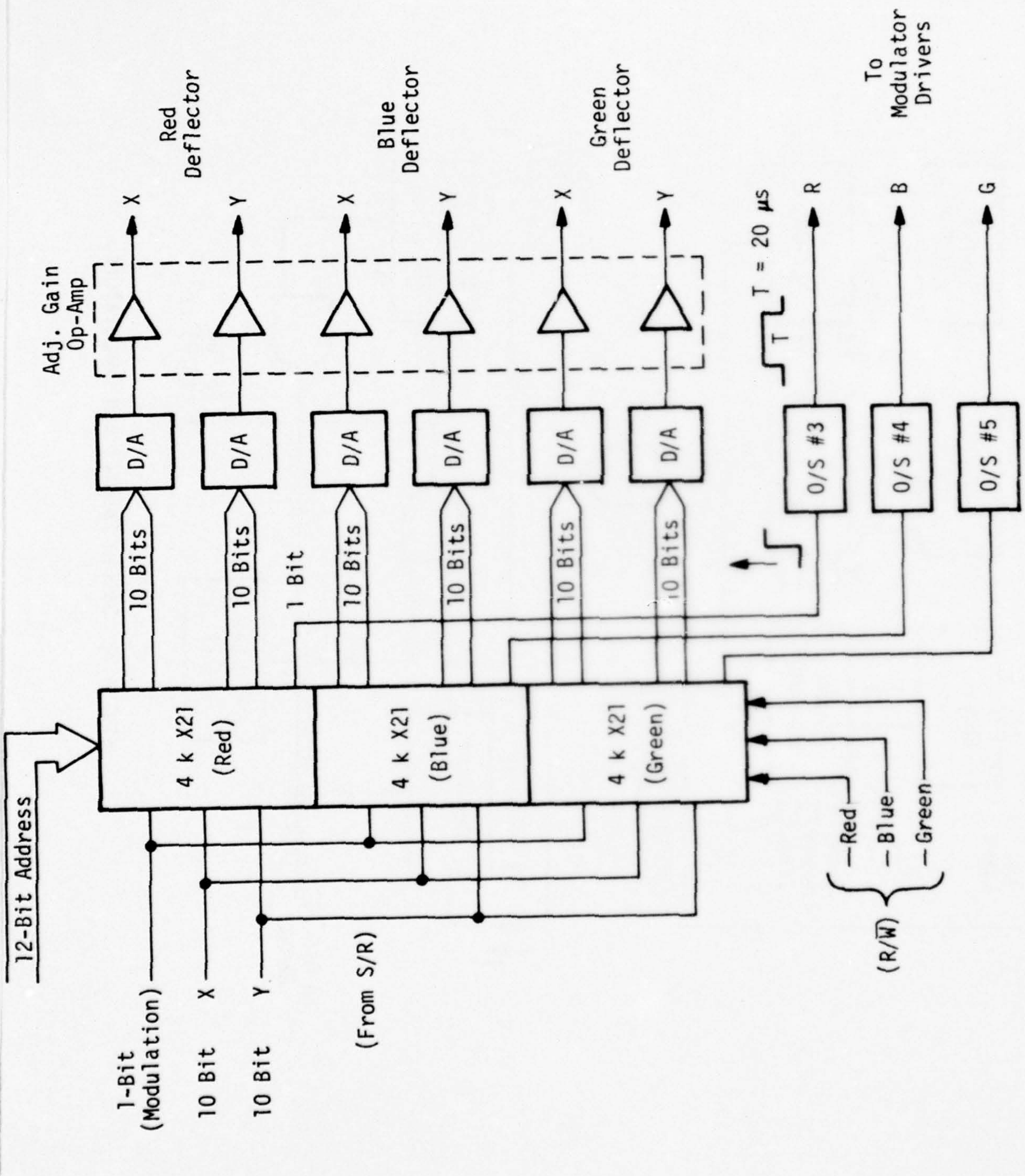

Figure 4. Memory and Deflectors.

code activates O/S numbers 3, 4, and 5 whenever a signal is present for the modulators to be On/Off. The outputs of the O/S then are fed to the drivers for the modulators. The time T=20 microseconds is chosen so that the modulators are kept off as long as a signal is present from the 3-bit code.

Figure 5. Memory Address. A 100 kHz clock is used to step the address counters every 10 microseconds through a driver gate. The counters should have a reset capability when the run is started. There are 21 bits out of each memory for the individual colors, making a total of 63 bits. The input is a 21 bit code for each color and controlled by the R/$\overline{W}$ gating from Figure 2.

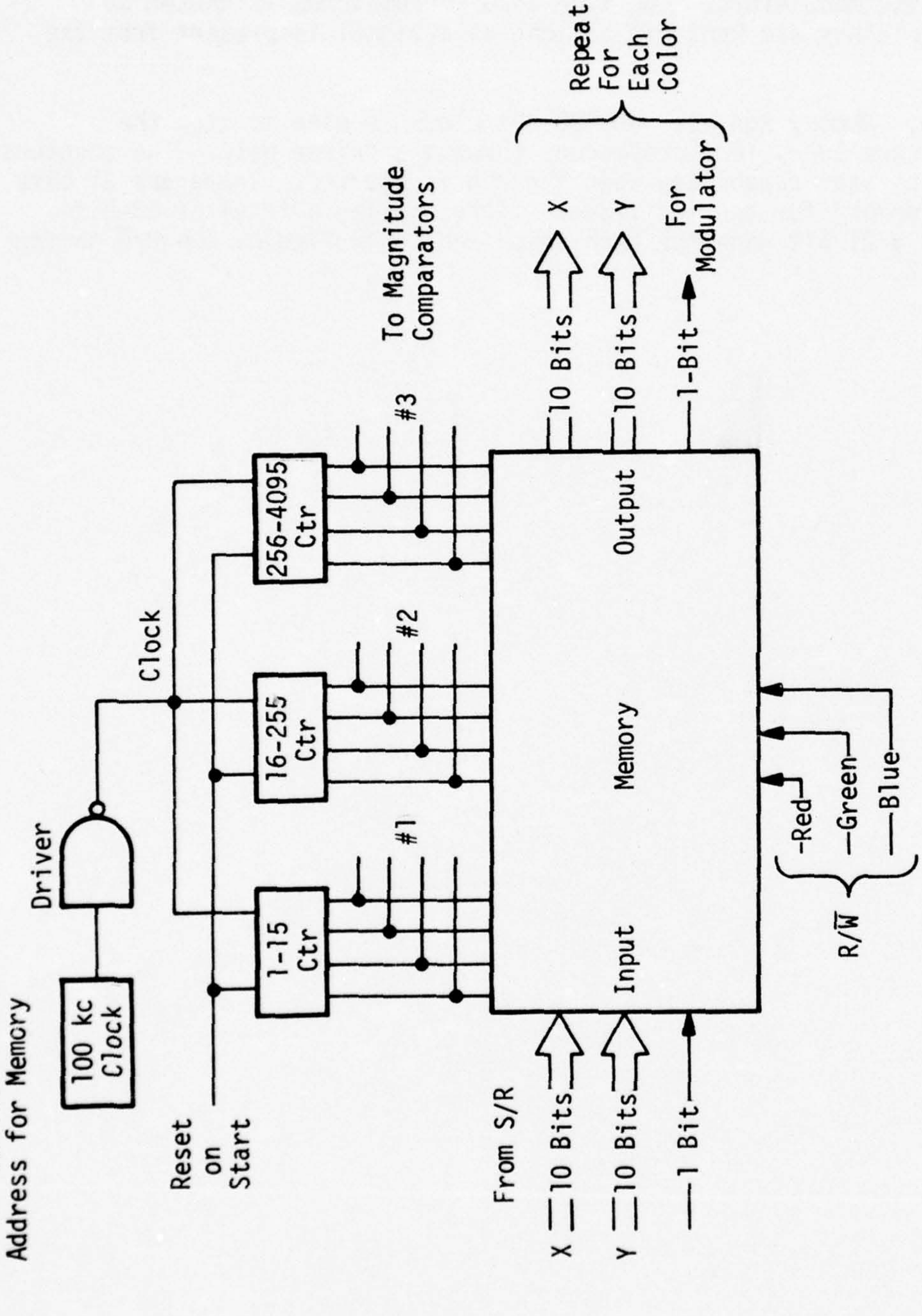

Figure 5. Memory Address.

SECTION V

DISCUSSION

It is not the purpose of this report to attempt a detailed theoretical explanation of the various types of deflection techniques that have been used in the past decade. This type of investigation has been performed by others. However, a summary of the techniques and related references used would be helpful in understanding the conclusions in this report.

Direct generation of a two-dimensional visual display by modulated light-beam scanning has been a long-sought goal. The laser's high brightness and directional characteristics allow light modulation and scanning techniques to be employed that were not feasible with conventional light sources. The lasers monochromatic light, available at a variety of wavelengths, allows color displays to be readily implemented.[5]

The brightness of a laser display is determined by screen size, laser power, optical system transmission efficiency, laser wavelength, and screen diffusion characteristics. Figure 6 shows screen brightness for a display with an optical transmission efficiency of 50 percent that uses an argon ion laser light source. It has been assumed that a rear-projection viewing screen is used for safety reasons. It can be seen that a one-watt laser would produce an image of 25 foot-lamberts (fL) on a 1.1 square-meter screen. Typical television viewing brightness levels are between 25 and 50 fL. Much larger and brighter displays could be produced with lasers that are presently available.

Figure 7 illustrates a stroke-writing display developed by McCarthy and Lipnick.[6] High-frequency galvanometers are used to write symbols at any desired point on the display screen. Since the laser light source is not scanned into a raster, but only directed into the areas where information is to appear, much brighter images are possible for a given laser power. Electrooptic light modulators are used to gate red, green, and blue laser lines on and off to write information in any of ten resolvable colors.

Symbols are formed by driving the orthogonal galvanometers in a programmed sequence of strokes. Galvanometer frequency-response limitations allow up to ten symbols to be generated with a 30-Hz refresh rate.

5 Baker, Charles E., "Laser Display Technology", IEEE Spectrum, pp. 39-50, Dec. 1968.

6 McCarthy, D., and Lipnick, R., "Large Screen Multicolor Laser Display for Trainer Applications." U.S. Naval Training Device Center, Orlando, FL.

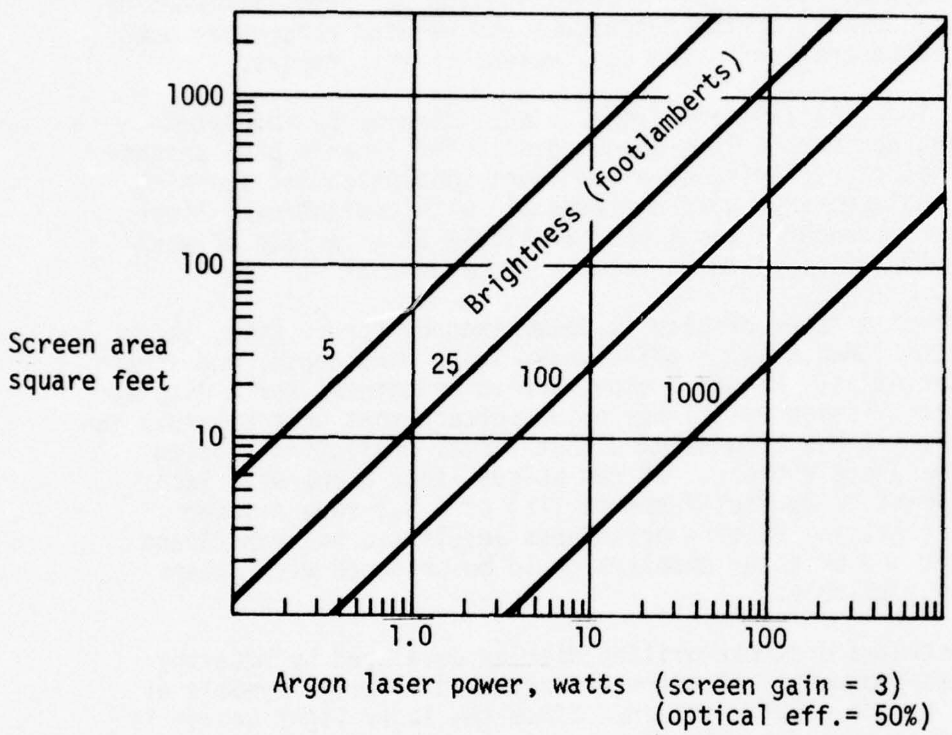

Figure 6. Laser Display Brightness.

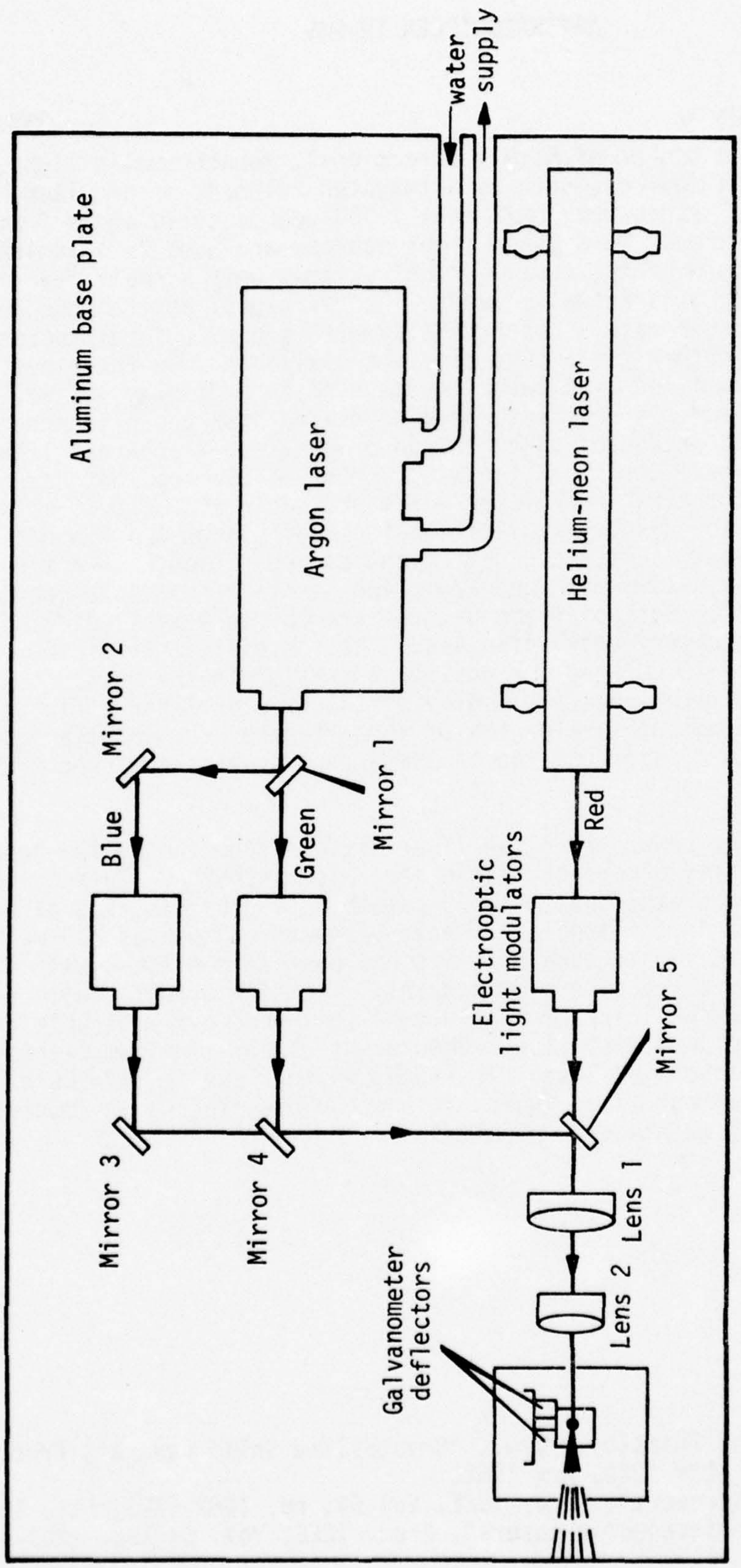

Figure 7. Stroke-writing Digital Laser Display.

LASERS

The laser is a source of highly directional, monochromatic light. Conventional light sources, such as a tungsten filament or arc lamp, are quite wasteful since they emit into a 360-degree solid angle from a relatively large area. When these light sources are used to illuminate the limited aperture of the usual optical system, only a small fraction of the emitted light is actually used. The additional optical complexities required to generate a color display with a conventional source tends to reduce further the amount of light available. On the other hand, all of the light emitted by a laser may be used in a display system. Light modulators and scanners have been developed over the past several years that take advantage of these unique properties of coherent light. Several reviews[7] have described the wide variety of lasers that have been developed since the first ruby laser was operated in 1960. Desirable laser properties for display application include: large amounts of visible output light, continuous operation, and operation with a minimum of equipment. The helium-neon and argon ion gas lasers satisfy most of these requirements. Both of these devices are commonly available and have been used in experimental displays. The low efficiency of the Krypton Laser has discouraged serious consideration in the past; however, new manufacturing techniques are improving the Krypton laser efficiency. Table 2 lists the output wavelengths of these lasers. Dominant spectral lines that contain a major portion of the output power are marked with asterisks.

The much higher power argon ion laser differs from the helium-neon laser in that it uses a more energetic electric discharge. This creates special cooling problems, but makes it possible to generate several watts of coherent light. Argon ion lasers have produced as much as 100 watts of blue-green coherent light; however, this has been accomplished with an efficiency of only a fraction of a percent. The high output powers available from an argon ion laser presently make this the most desirable device for display system implementation. The recent use of aluminum cathodes in the construction of the laser has increased the laser's life by a factor of three to four times, which is another plus factor in improving costs and reducing maintenance problems.

[7] Kiss, Z. J., and Pressley, R. J., "Crystalline Solid Lasers", Proc. IEEE, Vol. 54, pp 1236-1248, Oct 1966.
Bloom, A. L., "Gas Lasers", Proc. IEEE, Vol 54, pp. 1262-1275, Oct. 1966.
Nathan, M. L., "Semiconductor Lasers", Proc. IEEE, Vol. 54, pp. 1267-1289, Oct. 1966.

TABLE 2. GAS LASER WAVELENGTHS

LASER	WAVELENGTH A
Helium-neon	5939
	6046
	6118
	6294
	6328 *
	6352
	6401
Argon ion	4545
	4579
	4658
	4727
	4765
	4880 *
	4965
	5017
	5145 *
	5289
Krypton ion	4577
	4619
	4634
	4680
	4762 *
	4765
	4825
	4846
	5022
	5208 *
	5309
	5682 *
	6471 *
	6570
	6765
	6871

SCANNING

Any scanning technique that depends on physical motion of a refracting or reflecting surface is restrained to a sequential scanning motion. This is in contrast to the random deflection capability of the inertialess electron beam used in a cathode-ray tube. The desire to overcome these limitations has motivated the development of several electrooptical and acoustooptical scanning techniques. Figure 8 depicts the operating principle of one of the most successful nonmechanical scanning techniques.[8] The ultrasonic diffraction scanner depends on the fact that a stress wave can modify the refractive index of a transparent material such as glass or water. An ultrasonic stress wave propagating through a transparent material can affect light in a manner comparable to a ruled diffraction grating. The incident light beam is deflected by an angle directly proportional to the wavelength of the light and the frequency of the ultrasonic stress wave.

Depending on the interaction medium and the deflection angle required, the ultrasonic stress-wave frequency would be between 20 and 200 MHz. A typical unit has been developed that operates at a center frequency of 60 MHz with a bandwidth of 40 MHz. The acoustooptic interaction medium of the unit is a high-index glass, a ceramic piezoelectric transducer is employed, and operation in the Bragg diffraction mode allows nearly all of the incident light to be deflected in the desired direction.[9]

LIGHT MODULATION

Lasers that are suitable for display applications can be modulated by varying their input current, but only over a limited frequency range. There has been considerable interest in developing high-frequency light-modulation techniques for laser communication systems, and much of this work is directly applicable to laser displays. The most practical light-modulation devices utilize the Pockel's effect in an electrooptic crystal, such as KDP to control laser intensity in response to a control signal.[10] Figure 9 shows the type of transverse field electrooptic light modulator that has been used in several laser displays. This device is constructed from two identical pieces of 45-degree Z-cut potassium dideuterium phosphate (KD*P). These crystals, which are typically 2mm square and 35mm long, are arranged in tandem with their optical axes orthogonal. The electrical drive field is applied parallel to the optical axis. This type of fabrication is necessary to cancel out static birefringence and minimize the effect of changes in birefringence due to temperature variations.[11] An alternate

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[8] Gordon, E. I., "A Review of Acoustooptical Deflection and Modulation Devices", Proc. IEEE, Vol. 54, pp. 1391-1400, Oct. 1966.

[9] Adler, R., "Interaction between Light and Sound", IEEE Spectrum, Vol. 4, pp. 42-54, May 1967.

[10] Kaminow, I. P., and Turner, E. H., "Electrooptic Light Modulators", Proc. IEEE, Vol. 54, pp. 1374-1390, Oct. 1966.

[11] Eden, D. D., "Solid-state Techniques for Modulation and Demodulation of Optical Waves", DA 36039 AMC 03250E (DDC No. AD457311), U.S. Army Electronics Command, Feb. 1965.

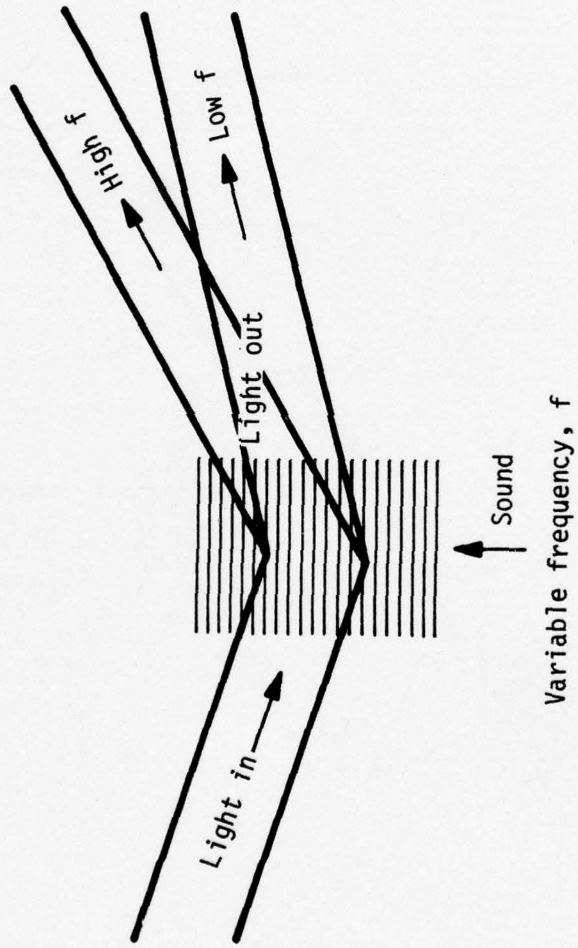

Figure 8. Ultrasonic diffraction scanner.

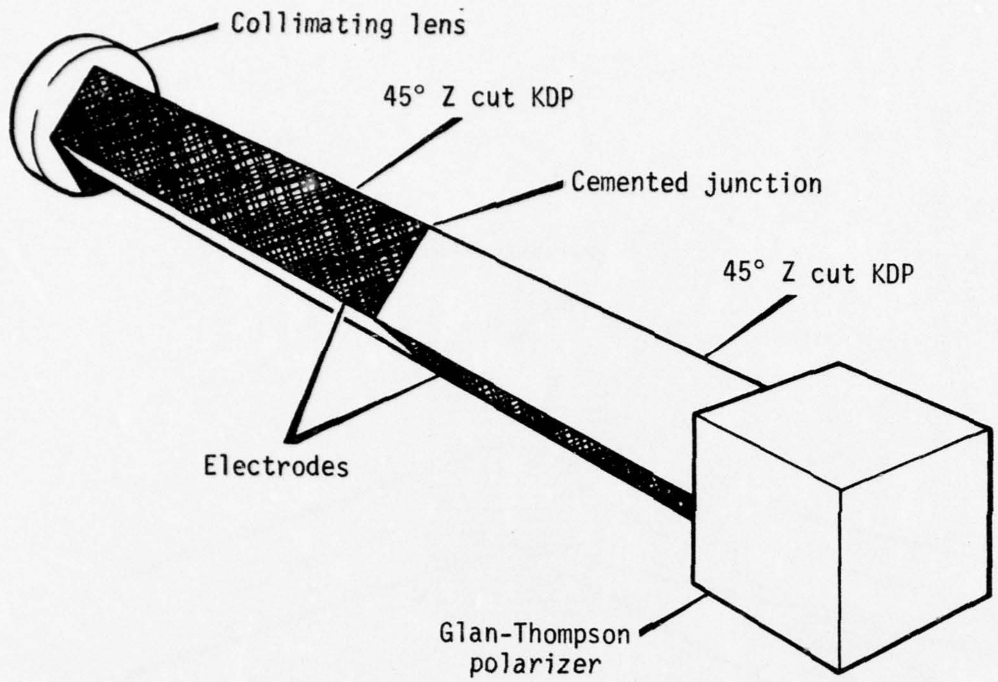

Figure 9. Transverse-field Electrooptic Modular Construction.

method of construction is to orient the optical axis of the two crystals in parallel with a 90-degree phase-retardation plate between the two crystals.[12]

Light modulation is performed by varying the polarization of an incident light beam. (See figure 10.) Linearly polarized light entering the crystal at the proper angle is separated into two orthogonal components, commonly called ordinary and extraordinary rays, each of which passes down the longitudinal axis of the crystal. Each component travels at a velocity depending on the index of refraction encountered in that particular path. Since the index of refraction for each component is affected by the applied voltage, a particular voltage will cause the two components to emerge exactly in phase. The result is that the transmitted light beam does not experience any change in polarization and thus cannot pass through an orthogonal polarization analyzer. By applying a voltage that causes the two component velocities to differ by an amount such that they emerge 180 degrees out of phase, the output polarization is orthogonal to the input light; thus, the analyzer does not produce any attenuation. At intermediate points between these two voltages, various amounts of elliptical polarization would result so that intermediate amounts of light would emerge.

Device parameters of interest for display applications include high transmission efficiency, large contrast ratio, adequate bandwidth, and low drive power. Less than 250 volts are required to vary the transmission of a transverse modulator from minimum to maximum. The older, longitudinal type of light modulator, which operated with an applied electric field in the direction of light-beam propagation, required 20 times this driving voltage.

Typically, contrast ratios of 100:1 and transmission efficiencies as high as 90 percent are exhibited by the transverse-field light modulator. Contrast ratio and transmission efficiency are primarily determined by light divergence, beam alignment with crystal axes, and scattering within the modulator. Drive voltage is determined by crystal geometry and the electrooptic coefficient. Several watts of optical power can be handled by a transverse-field modulator without taking special design precaution. Observe from figure 11 that the modulation is not linear over a full range of operation without compensation.[13]

Work has been performed using acoustooptic cells for modulators and a multiple color modulator.[14] The diffraction grating produced within the body of an acoustooptic cell is used both as a laser beam modulator and a deflector since both the diffraction beam intensity and angle can be

---

[12] Peters, C. J., "Gigacycle-bandwidth Coherent-light Traveling Wave Amplitude Modulator", Proc. IEEE, Vol. 53, pp. 455-460, May 1965.

[13] Foley, W. L., "A Study of Light Modulation & Scanning Techniques for Application to Simulation Display Generation", AD 637-307, Mar. 1966.

[14] Spaulding, R. A., Three Color Modulation Divided by Three, June 1974. Electrooptical System Design.

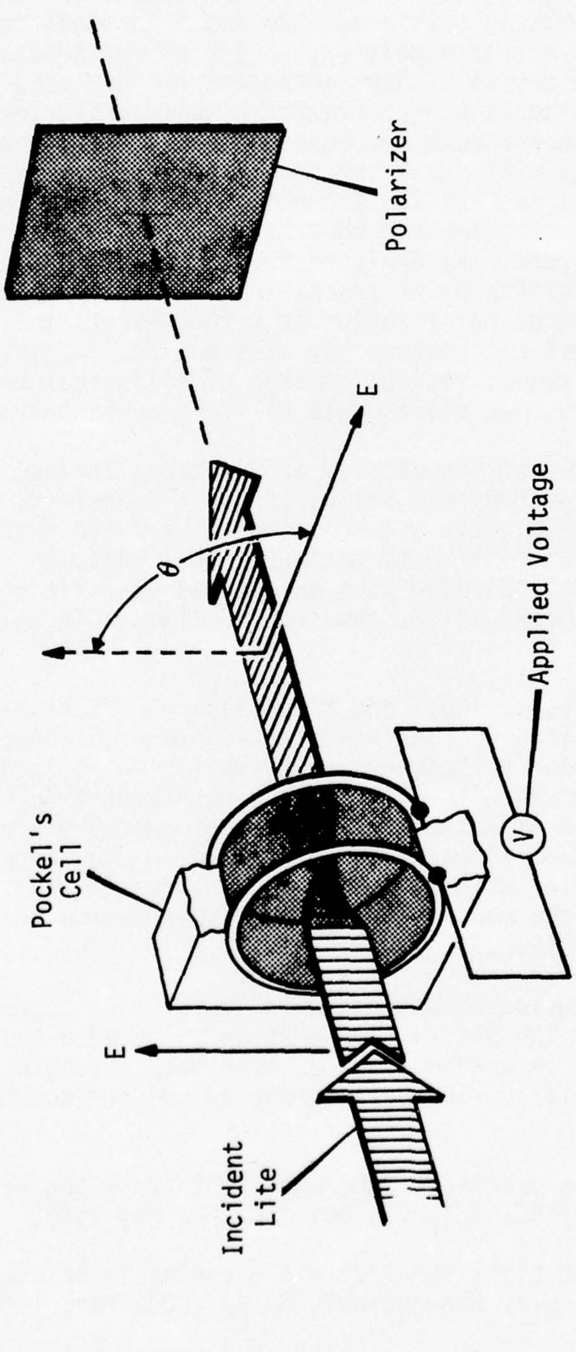

Figure 10. Pockel's Cell.

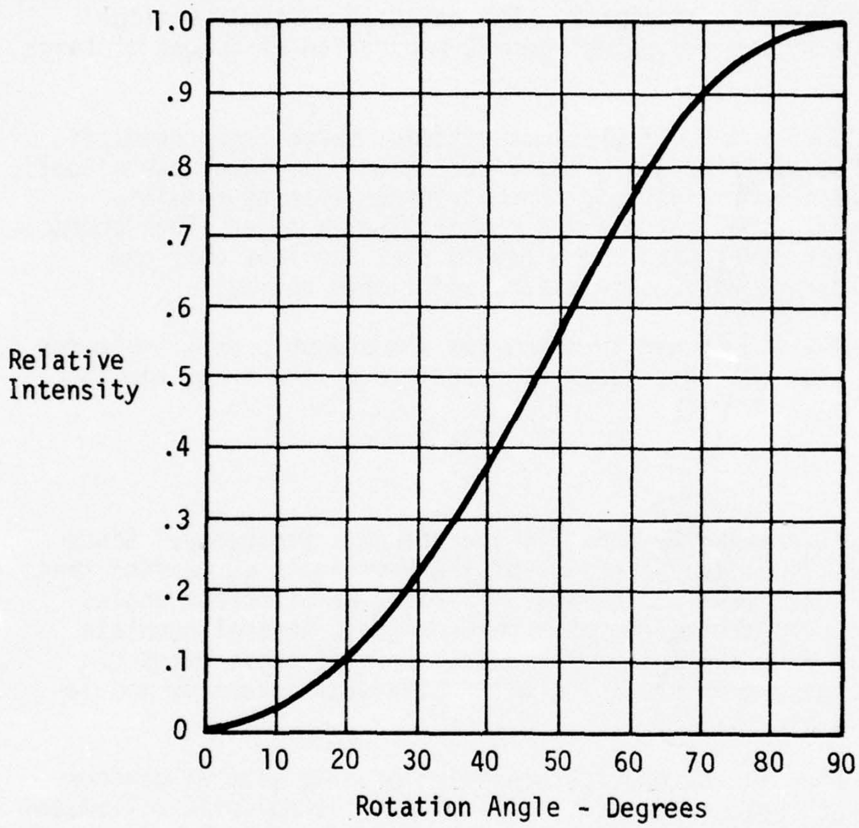

Figure 11. Intensity vs. Rotation Angle.

electronically controlled; however, by adding a spatial filter to the output and selecting the modulator drive frequency properly, it is possible to select a particular wavelength from a multicolor laser source. The color selection feature has made possible a technique whereby each output wavelength of a three color laser is modulated separately and simultaneously within a single acoustooptic modulator. The relatively simple optical systems associated with laser displays permit projection of images of large size.

CONVENTIONAL TECHNIQUES - In most previous systems, three laser beams of different wavelengths were intensity modulated using individual acoustooptic modulators. The obvious disadvantage is that three separate modulator channels are required. Thus there are a number of advantages, both economical and technical, for developing a new method that requires only one acoustooptic modulator, a multicolor laser, and simple optics.

DIFFRACTING THE BEAM - The manner in which the acoustooptic cell separates the color components of the laser beam is described by the Bragg equation:

$$\sin \frac{\theta}{2} \approx \frac{f\lambda}{2v}$$

where v is the acoustic velocity and f is the acoustic frequency. Since the angle of diffraction θ is a function of the wavelength λ, we find that the three incident laser wavelengths are diffracted at different angles (figure 12). Using a multiple-frequency drive signal, several complete beams can be created from one multicolor beam. Each of these beams can be modulated separately, thus providing both individual intensity modulation and angle selection ability.

DEFLECTION TECHNIQUES - The successful operation of many optical devices relies, among other things, on accurate directional control of a collimated beam of light. The control may be continuous, as in the form of a scan, or may be in the form of x and y data.[15]

Resolution of deflection methods is often referred to in texts; this means the number of resolvable spots which the beam may occupy. Fowler & Schlafer[16] use the Rayleigh criteria for resolution where a beam of half-angle divergence Θ deflected through an angle $\emptyset$ exhibits the resolution

$$N = \frac{\emptyset}{\Theta} = \frac{\emptyset w}{\lambda \varepsilon}$$

where w = beam width
λ = wavelength
ε = 1.25 for a circular beam of uniform intensity.

15 Holt, Donald, "Laser Beam Deflection Techniques", Optics Technology, pp. 1-7, Feb. 1970.

16 Fowler, V. J., & Schafer, J. A., Survey of Laser Beam Deflection Techniques, Proc. IEEE, Vol. 54, No. 10, 1968.

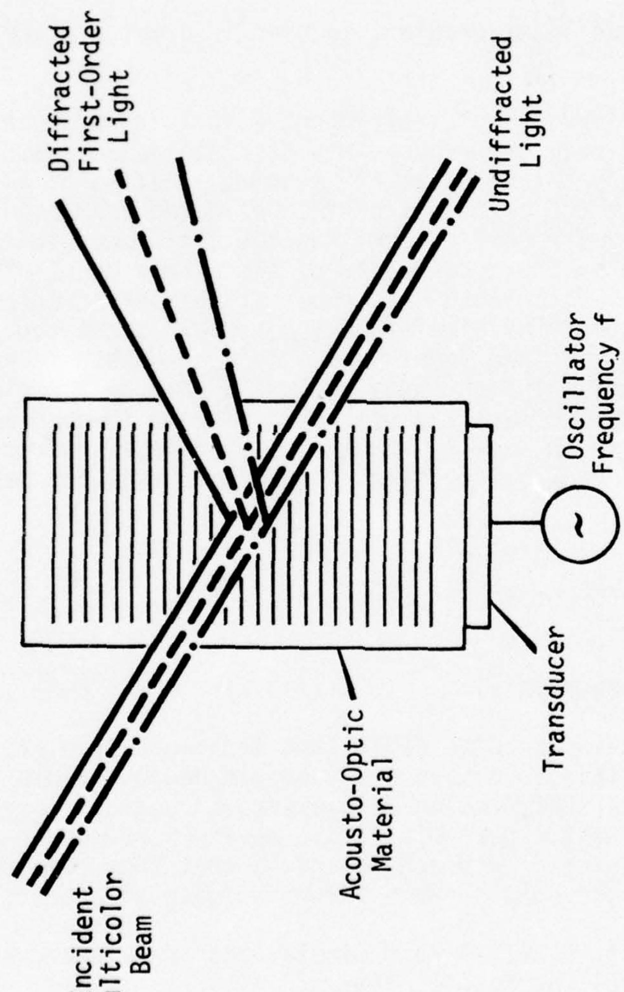

Figure 12. Separation of Laser Wavelengths by Acoustooptical Cell.

INTERNAL DEFLECTION - A version using a crossed array of $LiNbO_3$ electro-optic switches has been described by Dakss & Powell.[17] This device is capable of deflecting one watt power output to any of 7000 spots with micro-second switch speeds. A Yag laser is used, operating in the UV range, and having a lower wavelength than the visual range.

ELECTROOPTICAL DEFLECTION - These deflectors are of two types.

a. Electrooptic polarization modulator in conjunction with a birefringent polarization discriminator.

b. A linear refractive index gradient induced in a material by the electrooptic effect.

Deflection techniques involving birefringent discriminators are all digital, i.e., the output beam can occupy only discrete positions. These deflectors were reviewed by Kulcke et al.[18] A common feature of all digital deflection methods is that the positions of the deflected beam depend purely on the geometry of the birefringent element and the difference in the methods is basically a difference in the arrangement of the birefringent discriminator. Possibly the simplest deflection method is known as the split angle method. See figure 13.[19] Here a block of birefringent material is cut such that the optic axis is at an angle α to the input face. If α is chosen correctly, the ordinary ray of an incident light beam will pass through the block undeviated, while the extraordinary ray will be deflected through angle β. If the ordinary refractive index is n_o and the extraordinary refractive index is n_e, the corresponding orientation of the optic axis for maximum splitting is given by

$$\tan \beta = \frac{n_o}{n_e}$$

where the lateral deflection of the input beam is

$$d = W \tan \beta$$

where w is the width of the crystal.

The second basic type of electrooptic deflection technique involves the bending of light beams within an active electrooptic medium. This type of device has two advantages, their design allows for low optical losses, and the active material is almost a pure dielectric having a frequency response extending to microwave regions. A disadvantage is that they require low driver output impedances and considerable power for wideband operation. The

17 Dakss, M. L., & Powell, C. G., A Fast Digitalized Scan-laser, IEEE, J. Quantum Electronics, Vol. 4, No. 10, 1968.

18 Kulcke, W., Kosanke, K., Max, E., Habegger, M. A., Harris, T. J. & Fleisher, H., Digital Light Deflectors, Proc. IEEE, Vol 54, No. 10, 1966.

19 Kulcke, W., Harris, T. J., Kosanke, K., & Max, E., Res & Development, IBM J., Vol. 8, p. 64, 1964.
Nelson, T. J., Bell Syst., Tech. J. Vol. 43, p. 821, 1964.
Kulcke, W., Kosanke, K., Max, E., Fleisher, H., & Harris, T. J., Appl. Phys. Letts: Vol. 8, p. 266, 1966.

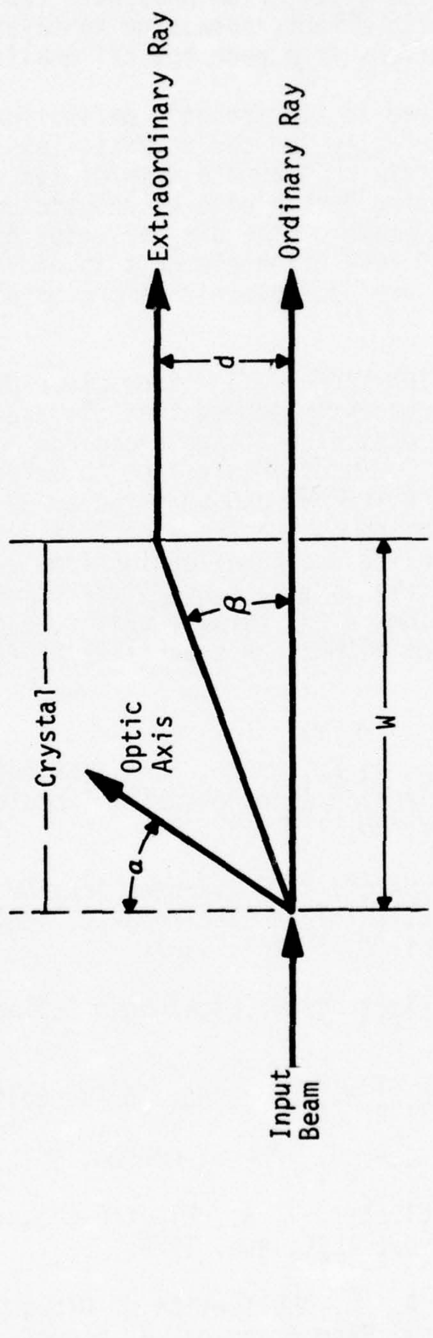

Figure 13. Birefringent Material.

method depends on setting up a refractive index gradient in a material. The materials of most interest to investigators are potassium dihydrogen phosphate (KDP) and potassium dideuterium phosphate (KD*P). A material which gives a high electrooptic effect, potassium tantalate-niobate, has been used by Chen, et al, but suffers from poor optical quality.[20]

The problems involved in electrooptic deflection are losses due to hysterisis, piezoelectrically induced acoustic losses, and inherent electric conductivity of the crystal. Adequate damping techniques are an essential feature of the engineering design of electrooptic deflectors as described by Kiefer, et al.[21] A state of the art deflector possesses a single-pass capability of about 500 resolution elements in wideband operation.[22] Microsecond switching rates are possible with improved piezoelectric damping techniques.

ACOUSTOOPTICAL DEFLECTION TECHNIQUES - Ever since Debye & Sears[23] and Lucas & Biquard[24] independently showed that ultrasonic waves of high frequency could act as optical gratings, research has continued to improve their findings. Use of this effect to deflect a laser beam was first mentioned by Giarola & Bileter[25] and verified by Aas & Erf[26]. A useful approach to the utilization of the acoustooptical effect in laser beam deflection is the so-called Bragg reflection from ultrasonic waves in water[27]. Recent improvements to a Bragg diffraction scanner[28] use a high index glass as the medium, a PZT ceramic driver, a center frequency of 60 MHz, with a bandwidth of 40 MHz. A capability of 400 spots is claimed for this device.

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20 Chen, F. S., Geusic, J. E., Kurtz, S. K., Skinner, J. G. & Wemple, S. H., Light Modulation & Deflection with Potassium Tantalate-niobate Crystals. J. Appl. Phys., Vol. 37, No. 1, 1966.

21 Kiefer, J. E., Lotspeich, J. R., Brown, Jr., W. P. & Senf, H. R., Performance Characteristics of an Electrooptic Light Beam Deflector, J. Quantum Electronics, Vol. 3, p. 261, 1967.

22 Lotspeich, J. F., Electrooptic Light-beam Deflection, IEEE Spectrum, Vol. 5, No. 2, 1968.

23 Debye, P., & Sears, F. W., Proc. Nat. Acad. Sci., Vol. 18, p. 409, 1932.

24 Lucas, R. & Biquard, P. J., Phy et Radium, Vol. 7, p. 464, 1932.

25 Giarola, A. J., & Bileter, T. R., Electro-acoustic Deflection of a Coherent Light Beam, Proc. IEEE, Aug. 1963.

26 Aas, H. G., & Erf, R. K., Application of Ultrasonic Standing Waves to the Generation of Optical Beam Scanning, J. Acoust. Soc. Am., Vol. 36, 1964.

27 Korpel, A., Adler, R., Desmares, P., & Watson, W. A Television Display Using Acoustic Deflection & Modulation of Coherent Light, Proc. IEEE, Vol. 54, 1966.

28 Baker, C. E., "Laser Display Technology", IEEE Spectrum, pp 39-50, Dec 1968.

MECHANICAL DEFLECTION TECHNIQUES - Several mechanical systems for deflecting a light beam using mirrors have been used successfully in the past. The frequency range is limited and normally operates at slow speeds. Multifaceted rotating mirrors have the advantage of sawtooth scanning but are still inertia limited. Schlafer & Fowler achieved wideband reflection scanning by using mirrors attached to piezoelectric shear transducers.[29]

COMPARISON OF DEFLECTION TECHNIQUES (See Table 3).[30]

One deflection method can only be compared with another on the basis of the requirements of a given application. Economic as well as performance factors may have to be taken into account in any system evaluation. No single deflection method is best suited to all applications, and even the best choice for an application may be economically prohibitive.

[29] Schlafer, J., & Fowler, V. J. A precision, High Speed, Optical Beam Steerer, 1965 Int. Electron Devices Meeting.

[30] Holt, Donald, "Laser Beam Deflection Techniques", Optics Technology, pp. 1-7, Feb. 1970.

TABLE 3. COMPARISON OF LASER BEAM DEFLECTION TECHNIQUES

Deflection System	Scan-Laser	Digital Scan-Laser	Birefringent	Electro-optic Refraction	Acoustic Standing Wave	Bragg Diffraction	Rotating Mirror
Reference #	16	16	17-20	21-22	26-27	28	-
Sinusoidal Scan	yes	no	no	yes	yes	yes	yes
Sawtooth Scan	yes	no	no	yes	no	yes	yes
Digital Scan	yes	yes	yes	no	no	yes	no
Deflection Voltage	100V	100V	700V	10kV	low	low	
Power	low	low	low	high	med	low	low
Deflection Rate (Hz)	10^5	10^6	10^6	5×10^5	10^4	30k	
Deflection Accuracy	high	high	high	low	low	high	low
Resolution (spots/cm)	200	7.3×10^3	10^6	500	200	400	500
Wideband Operation	yes	yes	yes	yes	no	yes	no
Color Capability	mono	mono	mono	mono	mono	mono	multi
Light loss	no	no	low	20%	low	75%	no
Phase-front Distortion	no	no	low	high	high	low	no

MEMORIES

TABLE 4. ESTIMATED SPEED AND COST OF 1975 MEMORY[31]

Device Type	Cents/Bit	Approx. Access Time (μs)	¢/Bit/μs
Core	0.63	1.0	0.63
Bipolar	2.5	0.1	0.25
MOS	0.25	1.0	0.25
CCD	0.13	100	126

TRENDS IN MEMORY - What will the distribution of technologies look like in the future? Several manufacturers supplied the trend information. See figure 14.

Monolithic systems projects a residual market for core of about one-fifth of future demand, with NMOS grabbing half the semiconductor market and PMOS cornering 30%.

Intel Memory Systems expects fast, 1k N-channel and low-cost 4k N-channel to capture 80% of new RAM design and assert that almost all semiconductor is outperforming core at lower cost.

Users familiar with core see: increased use of solid-state memories as cost/bit drops; continued core back-up for certain products; switch to solid-state for memories under 650 ns; increased use of CMOS as cost, chip size and availability improve; reduced emphasis on volatility as power back-up costs go down.

Digital computer controls make these observations and suggest that core back-up will continue until 4k chips and others become available, standardized, low-cost and reliable. They see the volatility argument going out the window as soon as semiconductor memory with power back-up beats core prices.

California Data Processors see core retaining the market for large main memories and CMOS taking over the small main stores. They see bipolar memory serving the microprocessor market. Standard Memories agree that core will continue to dominate above 32k bits where volatility and economy count. Dataram also sees core continuing strong in applications requiring large storage and high reliability where cycle time remains uncritical.

[31] Olson, K., Semiconductor and Core Memories, Jan 1975, Digital Design Handbook, pp. 14-18.

NEW APPLICATION AREAS - Mechanical memories will suffer some. Intel reports that users of head-per-track disk systems find inexpensive RAM and shift registers offer increased reliability at a competitive price. Drum users will be attracted to CCD systems selling for less than 0.2¢/bit in 1975. Basic/Four similiarly expects low cost CCD memories for mass storage in the last quarter of 1975. Although TI believes CCD memories will become a factor in bulk memory applications, they claim cost must drop and makers must demonstrate availability of large quantities to break into this market. One commonly used tool to relate memory forms is a plot of capacity versus access time (figure 14).[32]

Tables 5 and 6 are specifications for rotating memories and equivalent Charge Coupled Device characteristics.

TABLE 5. STATE OF THE ART ROTATING MEMORY CHARACTERISTICS

Capacity	0.5 to > 1000 megabits
Access Time	2.5 to > 100 milliseconds
Data Rate	1.0 to 6.0 megabits/sec per channel
Power	50 watts and up
Weight	20 pounds and up
Error Rate	1 in 10^{11}
Non-volatile Memory	

Reliability is probably the most significant limitation for rotating memories. A low mean-time-between-failure (MTBF) figure results from predictable bearing failure mechanisms and the need for relatively complex electronic circuitry for track selection and read and write functions. Planned periodic refurbishments provide a solution for the bearing failure rate problem, but they are costly and troublesome.

Maintainability is another cumbersome aspect of rotating memories. Because of the unique characteristics of discs and drums, they require special skills, facilities, and equipment to maintain.

[32] Chambers, J. M., Sauer, D. J., Kosonocky, W. F., CCD's as Drum and Disc Equivalents, Sep. 1974, Western Electronic Show & Convention.

TABLE 6. DRUM AND CCD EQUIVALENT CHARACTERISTICS

	Drum	CCD Equivalent
Tracks (Loops)	256	1024
Bits per track (net)	32,768	8192
Data Rate	2 MHz	2 MHz
Access Time (max) (avg)	20 msec 10 msec	4 msec 2 msec
Useable capacity	8,388,608	8,388,608
Volume	3 cubic feet	1/3 cubic feet
Weight	125 pounds	15 pounds
Power	300 watts	5 watts operating, 2 watts standby
MTBF	3500 hours	20,000 hours

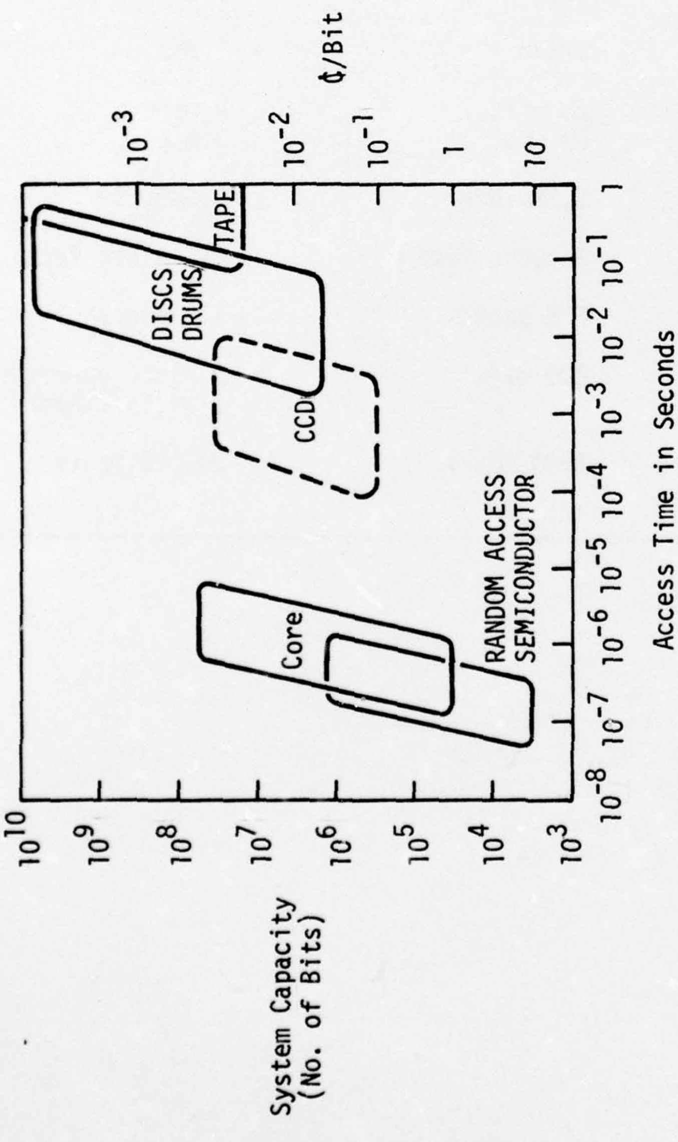

Figure 14. Memory Hierarchies.

RCA's Government and Commercial Systems Division, Van Nuys, CA, is working with a CCD equivalent of an 8-million-bit drum memory. It is only a tenth the size of the drum, weighs an eighth as much, operates four to eight times faster, and consumes 1/60th the power (see table 6.)

The sole, overwhelming consideration which will determine the long range success or failure of CCD memories is their cost. Since their access time is generally poorer than that of other forms of all-electronic memory, they must offer the user a cost advantage to be accepted. Compared to MOS RAM's, which seem to offer the closest competition costwise, CCD memories will have to ultimately be no more than half and perhaps as low as one-fifth the cost in order to be widely used. The potentially large number of bits per chip and the very low system overhead costs should make the one half factor readily achievable and the one fifth factor a challenging goal.

In summary, CCD's offer a direct answer to the problem of finding a cost-competitive, all-electronic counterpart to rotating mass memories. The only apparent shortcoming of the technology is the volatile nature of the memory devices, but for most applications this does not appear to be a genuine problem.

SPECIFICATIONS ON STATE OF THE ART MEMORY - Two typical CCD devices are as follows:

a. CCD 450, Fairchild
   1024 x 9 Bits, 18 Pin
   Dynamic
   Power Dissipation - 25 uw/Bit
   Cost - 1¢/Bit

   * Expect lower cost to be 0.1¢/Bit

b. CCD 460, Fairchild
   16 K Bits, 22 Pin
   Dynamic
   Power Dissipation - 20 uw/Bit
   Cost - 0.4¢/Bit

   * Expect 2 uw/Bit and 0.01¢/Bit by 1976

TWO TYPICAL RANDOM ACCESS MEMORIES ARE:

a. Semi 4402, EMM
   4096 x 1
   Static
   Pdis - 100 uw/Bit
   Cost - 2¢/Bit

b. 2602, Intel
   1024 x 1, 16 Pin
   Static
   Pdis - 200 uw/Bit
   Cost - 2¢/Bit

SECTION VI

CONCLUSIONS

A three-color laser system is no problem at this date but a five to six color system would be preferred. This leads to higher cost because of the additional memory, lasers, and the beam deflection systems. It can be assumed that, at the present prices, each additional color above three will add $5,000 to the initial cost. This includes the laser, beam deflection systems, and additional memory.

Most of the effort of this writer was spent in investigating the beam deflectors. An inertialess deflector such as an acoustooptic device would be ideal because of its speed compared to a mechanical deflector. The problem at this date is still the same problem as in the past. There is 50% light loss per deflector, which adds up to 75% for an x-y system. A resolvable 500 beam-diameter deflection is now state of the art but a 1000 BD deflector could be obtained. This would involve manufacturing research and would no doubt be of high initial costs. The simple and practical answer for wide-angle deflection and high efficiency is to use fast galvonometers. This is still cheaper than the preferred acousto-optic deflectors, and will give a greater deflection angle, but in turn it offers maintenance problems and slower deflection. Table 3 shows the comparisons of the various deflection techniques.

An explanation of the various types and specifications of memories is covered in this report. At this date, the writer assumes that a design of the memory needed for this laser projector would become obsolete while this report is being read. The use of charge-coupled devices for memories appears to be the most practical approach as to price, size, and power consumption. Though they are not as fast as Bipolar memories, they would be more than applicable in this situation. If the claims of manufacturers of CCD's are to be believed, the end of 1975 should have a perfect, off-the-shelf, low-power, memory device.

SECTION VII

RECOMMENDATIONS

This design does not offer the capability of symbol writing and of tracking without a past memory. As stated in the conclusion, a design of a memory at this time would be impractical because greatly improved devices will be available soon. When a memory is finalized for this design, it would be wise to integrate these two features. It would change the total price insignificantly and add desirable features to the overall large screen laser display system.

REFERENCES

1. Wolff, H. H., "Plotting Projector", U.S. Patent #3,739,370, June 1973, NAVTRAEQUIPCEN.

2. Senf, H. R., Laser Displays, SMPTE Report #100-2, Oct. 1966.

3. Thomas, Paul G., Large Screen Displays, Space/Aeronautics, May 1967.

4. Kidd, E. T., "Lasers for Training Devices - Final Report", Technical Report, NAVTRADEVCEN 1651, Sep 1965.

5. Baker, Charles E., "Laser Display Technology", IEEE Spectrum, pp. 39-50, Dec. 1968.

6. McCarthy, D., and Lipnick, R., "Large Screen Multicolor Laser Display for Trainer Applications." U.S. NAVTRADEVCEN, Orlando, FL.

7. Kiss, Z. J., and Pressley, R. J., "Crystalline Solid Lasers", Proc. IEEE, Vol. 54, pp. 1236-1248, Oct. 1966.
Bloom, A. L., "Gas Lasers", Proc. IEEE, Vol. 54, pp.1262-1275, Oct. 1966.
Nathan, M. L., "Semiconductor Lasers", Proc. IEEE, Vol. 54, pp.1267-1289, Oct. 1966.

8. Gordon, E. I., "A Review of Acoustooptical Deflection and Modulation Devices", Proc. IEEE, Vol. 54, pp. 1391-1400, Oct. 1966.

9. Adler, R., "Interaction between Light and Sound", IEEE Spectrum, Vol. 4, pp. 42-54, May 1967.

10. Kaminow, I. P., and Turner, E. H., "Electrooptic Light Modulators", Proc. IEEE, Vol. 54, pp. 1374-1390, Oct. 1966.

11. Eden, D. D., "Solid-state Techniques for Modulation and Demodulation of Optical Waves", DA 36039 AMC 03250E (DDC No. AD457311), U.S. Army Electronics Command, Feb. 1965.

12. Peters, C. J., "Gigacycle-bandwidth Coherent-light Traveling Wave Amplitude Modulator", Proc. IEEE, Vol 53, pp. 455-460, May 1965.

13. Foley, W. L., "A Study of Light Modulation & Scanning Techniques for Application to Simulation Display Generation", AD 637-307, Mar. 1966.

14. Spaulding, R. A., Three Color Modulation Divided by Three, June 1974, Electrooptical System Design.

15. Holt, Donald, "Laser Beam Deflection Techniques", Optics Technology, pp. 1-7, Feb 1970.

16. Fowler, V. J., & Schafer, J. A., Survey of Laser Beam Deflection Techniques, Proc. IEEE, Vol. 54, No. 10, 1968.

17. Dakss, M. L., & Powell, C. G., A Fast Digitalized Scan-laser, IEEE, J. Quantum Electronics, Vol. 4, No. 10, 1968.

18. Kulcke, W., Kosanke, K., Max, E., Habegger, M. A., Harris, T. J. & Fleisher, H., Digital Light Deflectors, Proc. IEEE, Vol. 54, No. 10, 1966.

19. Kulcke, W., Harris, T. J., Kosanke, K., & Max, E., Res & Development, IBM J., Vol. 8, p. 64, 1964.
Nelson, T. J., Bell Syst., Tech. J. Vol. 43, p. 821, 1964.
Kulcke, W., Kosanke, K., Max, E., Fleisher, H., & Harris, T. J., Appl. Phys. Letts: Vol. 8, p. 266, 1966.

20. Chen, F. S., Geusic, J. E., Kurtz, S. K., Skinner, J. G. & Wemple, S. H., Light Modulation & Deflection with Potassium Tantalate-niobate Crystals. J. Appl. Phys., Vol. 37, No. 1, 1966.

21. Kiefer, J. E., Lotspeich, J. F., Brown Jr., W. P. & Senf, H. R., Performance Characteristics of an Electrooptic Light Beam Deflector, J. Quantum Electronics, Vol. 3, p. 261, 1967.

22. Lotspeich, J. F., Electrooptic Light-beam Deflection, IEEE Spectrum, Vol. 5, No. 2, 1968.

23. Debye, P., & Sears, F. W., Proc. Nat. Acad. Sci., Vol. 18, p. 409, 1932.

24. Lucas, R. & Biquard, P. J., Phys et Radium, Vol. 7, p. 464, 1932.

25. Giarola, A. J., & Billeter, T. R., Electro-acoustic Deflection of a Coherent Light Beam, Proc. IEEE, Aug. 1963.

26. Aas, H. G., & Erf, R. K., Application of Ultrasonic Standing Waves to the Generation of Optical Beam Scanning, J. Acoust. Soc. Am., Vol. 36, 1964.

27. Korpel, A., Adler, R., Desmares, P., & Watson, W. A Television Display Using Acoustic Deflection & Modulation of Coherent Light, Proc. IEEE, Vol. 54, 1966.

28. Baker, Charles E., "Laser Display Technology", IEEE Spectrum, pp. 39-50, Dec. 1968.

29. Schlafer, J., & Fowler, V. J. A Precision, High Speed, Optical Beam Steerer, 1965 Int. Electron Devices Meeting.

30. Holt, Donald, "Laser Beam Deflection Techniques", Optics Technology, pp. 1-7, Feb. 1970.

31. Olson, K., Semiconductor and Core Memories, Jan 1975, Digital Design Handbook, pp. 14-18.

32. Chambers, J. M., Sauer, D. J., Kosonocky, W. F., CCD's as Drum and Disc Equivalents, Sep. 1974, Western Electronic Show & Convention.

APPENDIX A

SUMMARY OF STUDIES ON LASER DISPLAYS

1. Laser Display, Toshio Sato, U.S. Army Foreign Science & Technology Department, Nov. 71, AD 888-976.

Rayleigh Criterion for resolution was used to investigate the electrooptical deflection. Recommended using a laser display for a large screen display and mirrors for deflection techniques.

2. Display Addressing: Cybrowski, W., Fort Monmouth, Sep. 1973, AD 913786.

Investigated the use of lasers and hybrid acoustooptical deflection for writing on photo-chromic film. Results showed acoustooptics well suited for high-speed x-y axis if 75% light loss could be tolerated (50% for x, 50% for y). Use was made of an Isomet deflector TeO_2, paratellurite.

. The angular deflection was 40 mradians.

. 400 x 400 spots.

. Character generator: 64 upper case ASCII using Motorola ROM MOS, 2240 bits.

Evaluation of two types of deflection showed:

. Acoustooptic - fast deflection speed of 10 micro-second, 50% efficiency per stage.

. Galvanometers mirrors - low loss, 99% efficiency per mirror, slow speed of about one kHz.

3. Laser Beam Scanning, Yoder, Paul.

Perkin, Elmer, for Rome Air Development Center, AD 612725.

Investigated techniques for modulating and scanning a laser beam to form a visual display.

Results: Using an electrooptic scanner, Barium Titanate ($BaTiO_3$), for horizontal scanning, the results were negative.

4. Broad-Band Laser Digital Deflector, Ruppe, D., Everett, S. C., Cicero, R., IBM for Fort Monmouth, AD 651220.

Abstract: Provide a beam deflection concept from 450 nm - 700 nm. A design was achieved for a deflector that provided 1024 discrete beam positions in x and y for 632.8 nm (red). The digital deflectors consist of 10 calcite crystals and 10 electrooptic modulators. The system proved to be expensive and funding was discontinued before further work could go on.

5. Acoustooptic Laser Display System, Green, Harold

Naval Air Development Center, Warminster, Pennsylvania

Society for Information Display, "Digest of Technical Papers", 1974, pp. 56-57.

A practical laser display using advanced concepts of acoustooptic deflection techniques was designed and built by Isomet Corporation with the following characteristics:

- Wavelength - 632.8 nm
- Life - 10,000 hours
- Access Time - 10 micro-seconds
- Deflector Angle $\pm$ 2 degrees

The system consists of a beam separator, 4 x inverse telescope, 15 mw HeNe laser, acoustooptic modulator and deflector.

Results:

- Overall system worked out well
- Clear presentation of symbols
- Small amount of speckle
- 500 x 500 SCAN-STROKE

6. Study of Light Modulation & Scanning Techniques for Application to Simulation Display Generation, Foley, W. L., Wright-Patterson AFB, Human Factors 3/66, AD 637307.

The study showed that the only solid-state method of scanning random-access is with acoustooptics. Sufficient deflection is available for 500 x 500 spots. Using an inverse telescope of 10 power scope reduces the beam divergence ϕ to $\phi/10$ while expanding the diameter of the beam by a factor of 10.

7. Selective Access Laser Display Beam Positions.

Lotspeich, J. F., Brown, W. P., Kiefer, J. E., of Hughes Res. Labs for Rome ADC. (Hnat, Stephen), 1/67, AD 646619.

Requirement was for:

- 1000 x 1000 resolvable spots
- Micro-sec response

- Random deflection
- Flexible format
- Multi-colors

A study was made using an electrooptic prism (KD*P). Results showed that 750 resolvable spots was maximum.

8. Laser - PC Large Screen Display System.

Christian, W. J., Norenberg, L. P., NELC, San Diego 10/72, AD 907-495L.

Beam deflection galvanometers were investigated from the CEC Division of Bell & Howell. Results showed ±20° was easily obtainable and the laser was used as the writing beam.

9. Large Screen Laser Display Study, Houston, T. O., NELC 10/70, AD 877854.

Effort was concentrated on an "Internally Deflected Beam". Project proved unsuccessful.

10. Investigations on the Readability and Interpretability of Electronic Displays. Beyer, R., Schenn, H. D., Zietlow, E., Royal Aircraft Establishment 9/73.

Work was done on investigations of the effectiveness of brightness and color coding in screen displays by R. Beyer (et al). The effects of various types of coding (color, size, form, value of symbols) and the detectability of the coded symbols were obtained. The conclusions were that there is little difference between the performance achieved with brightness-coded displays and color coded displays in simulation of typical tasks. However, if the two types of coding appear simultaneously in an arrangement of different displays, then the performance achieved with color coded displays was more uniform, whereas the performance in the tasks associated with brightness-coded displays was more unfavorable.

LASER COST BREAKDOWN

	Cost (K$)
1. Krypton Laser	10
2. Three color Electrooptic Modulator	6
3. x-y Deflector, Galvanometers	1 ea.
4. Drive Amplifiers	1 ea.
5. Dichroic Filters (3)	1

Manufacturers such as Isomet and General Scanning have been active in supplying lasers and deflection systems to various Government laboratories. There are enough manufacturers of the above supplies to be able to buy off-the-shelf items.

LASER SPECTRAL LINES, POWERS AVAILABLE, LUMINOUS EFFICIENCY AND LUMENS OUTPUT

1 watt Krypton-Argon Mix (5 best)

λnm	mW	Lum Eff	Lumens	Color
647.1	200	.126	17.1	Red
568.2	80	.729	39.6	Yellow Green
514.5	200	.598	81.0	Green
488.0	200	.193	26.0	Blue Green
476.5	60	.123	5.0	Blue

15 mW Argon

λnm	mW	Lum Eff	Lumens	Color
514.5	10	.598	4.1	Green
488.0	5	.193	.7	Blue Green

15 mW HeNe

λnm	mW	Lum Eff	Lumens	Color
632.8	15	.241	2.3	Red

1 watt Krypton

λnm	mW	Lum Eff	Lumens	Color
676.4	120	.022	1.8	Red
647.1	500	.126	42.7	Red
568.2	150	.729	74.3	Yellow Green
530.9	200	.873	118.8	Yellowish Green
520.8	70	.727	34.6	Green
482.5	30	.154	3.1	Blue
476.2	50	.118	4.0	Blue

2 watt Argon

λnm	mW	Lum Eff	Lumens	Color
514.5	800	.598	325.3	Green
501.7	140	.357	34.0	Green
496.5	300	.284	57.9	Bluish Green
488.0	700	.193	91.9	Blue Green
476.5	300	.123	25.1	Blue
472.7	60	.095	3.9	Blue
465.8	50	.077	2.6	Blue
457.9	150	.055	5.6	Purplish Blue

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